NASA Earth Science Enterprise Technology Planning Workshop

Overview of Key Technology Areas

Fuk Li

New Millennium Program

Jet Propulsion Laboratory, California Institute of Technology

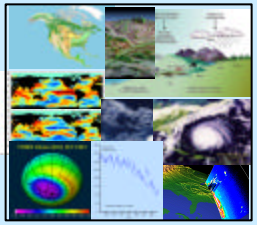
January 23-24, 2001
Hyatt Arlington Hotel - Arlington, VA

NMP Program

Develop Technology Validation Needs Inventory

- Analyze Earth Science capability needs
- Capitalize on pipeline investments
- Require strong flight validation rationale

Earth Science Research Plan



Baseline Measurement Studies

Earth Science Vision

Outside Technology Pipeline

- **Cross Enterprise Technology**
- **Other Agencies**
- **Industry**

Emerging Technology

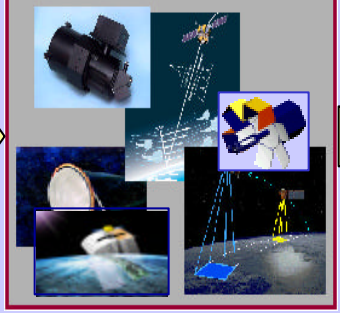
ESTO
Earth ScienceTechnology Office

- **Instrument Incubator**
- **Advanced Technology Initiatives**
- **Advanced Information Systems Technology**

New Millennium Program

Flight Validation Rationale

Earth Science Technology Validation Needs



Future ESE Mission

NMP Process
Development of Earth Science Flight Validation Needs Inventory

- Identified key emerging technologies requiring flight validation
  - Six “Mini” Workshops held 3/00-8/00
  - Technology Roadmaps and Strawman Mission scenarios created for each technology area
  - Integrated technology plans developed with ESTO where flight validations are needed

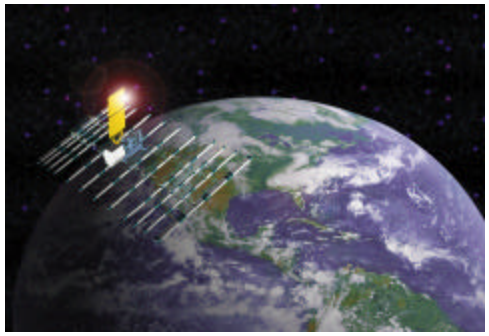
- Examples of Workshop products shown in subsequent charts
  - Benefits
  - Technology Roadmap
  - Strawman Mission scenario
  - Integrated technology plans

- Full sets of charts provided in breakout sessions

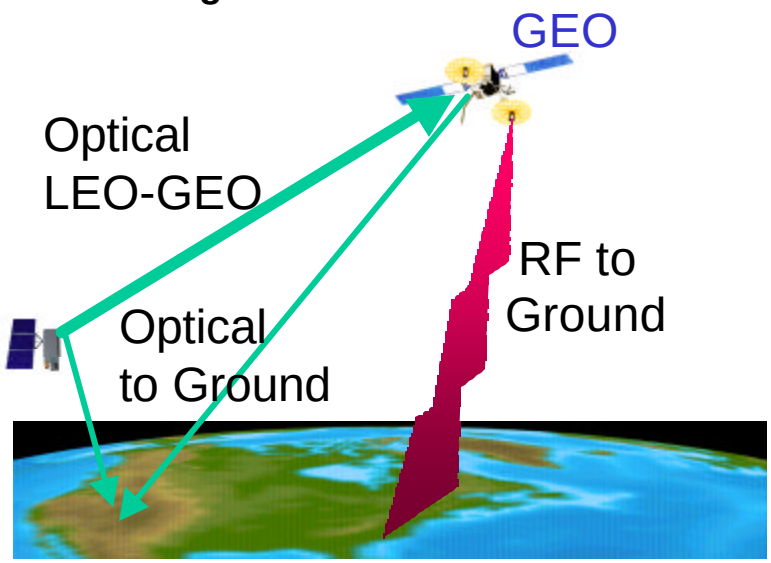
Emerging Technology Subsystem Themes

Several recurring technology subsystem validation "themes" have emerged. Each technology theme benefits a broad set of Earth Science measurements.

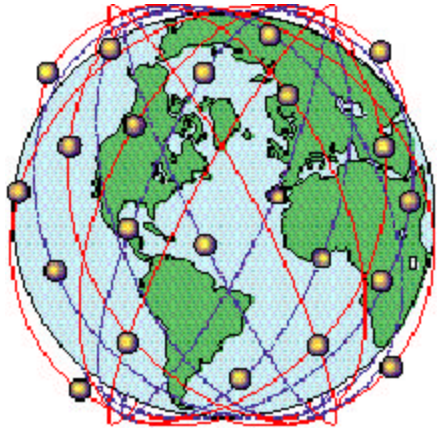
Large Deployable Microwave/ Millimeter Antennas



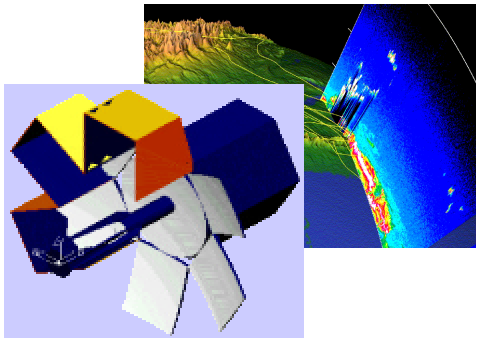
Ultra-High Data Rate Communications



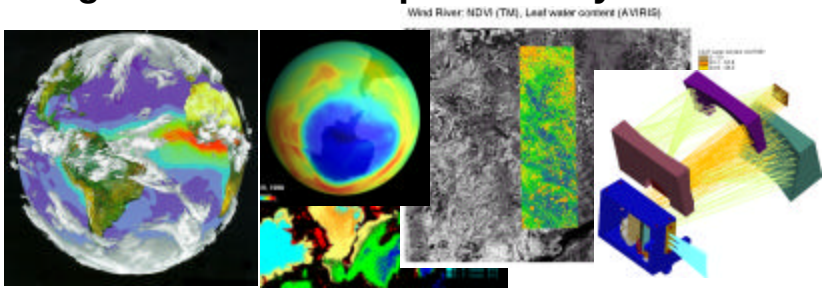
Autonomous Constellation Control/Operation



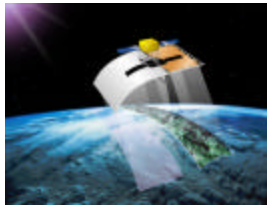
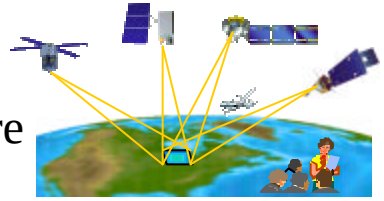
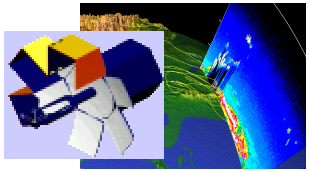
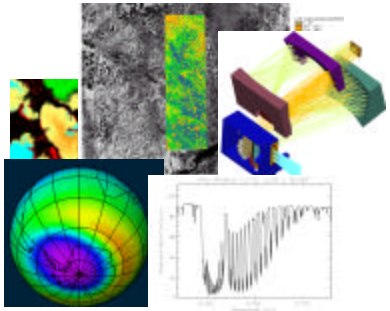
Large Deployable Visible/IR Optics



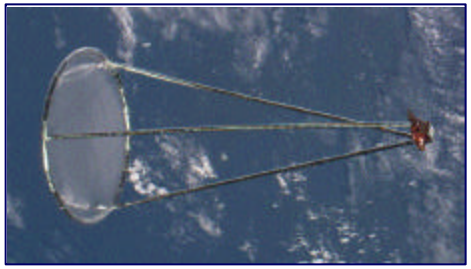
High Performance Spectrometry



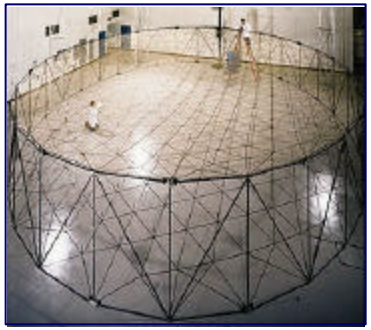
Summary of "Mini" Workshop Key Findings

Workshop Title	Key Conclusions	Next Steps
Large, Light-Weight Deployable Antennas 	Needed for multiple missions • Soil Moisture, SAR's, Rain Radar • Planar, Cyl, & Reflectors	Trade Studies: • Component vs. subsystem • Antenna type - hybrid? • Identify partners
Intelligent Distributed Spacecraft Infrastructure 	Flight validation required: • Spacecraft formation flying command and control – Global Precipitation Measurement • Virtual platforms - system validation needed?	Trade Studies: • Subsystem tests vs. system • Refine user requirements
Ultra-High Data Rate Communications 	Multiple needs identified. Optical comm and ultra high rate RF components require flight validation	•Experiment partners •Technology development for W & V-Band, Tera-Hz
Light-Weight, Deployable UV/Visible/IR Telescopes 	Needed for DIAL • Tropospheric chemistry • Deployment, stability need flight validation	•Identify other customers – IR Imaging? •Refine validation needs •Identify flight partners
High Performance Spectrometry • Hyperspectral Land/Ocean • Atmospheric Physics/Chemistry 	Hyperspectral customers/needs • Land/Ocean hyperspectral • S/N, stability, swath width Atmospheric customers/needs • Trop/Strat Chemistry • Greenhouse gas monitoring • Clouds/Aerosols •Fast, high dispersion optics	• Other communities needs/ capabilities? • Spectral range (>2.5µm?) • Leo/GEO S/N, resolution • On-board processing needs • On-orbit calibration needs • Pointing/stability systems

Large Deployable Antennas Benefit Multiple Earth Science Applications

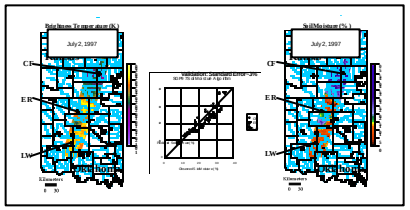


Large Deployable Mesh Antenna



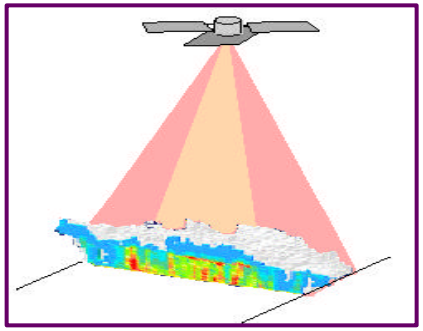
Planar Array Antenna

Soil Moisture Measurements



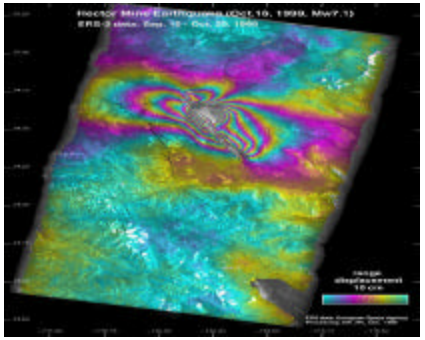
- 25m class antennas for 10km horizontal resolution

Global Precipitation Measurements



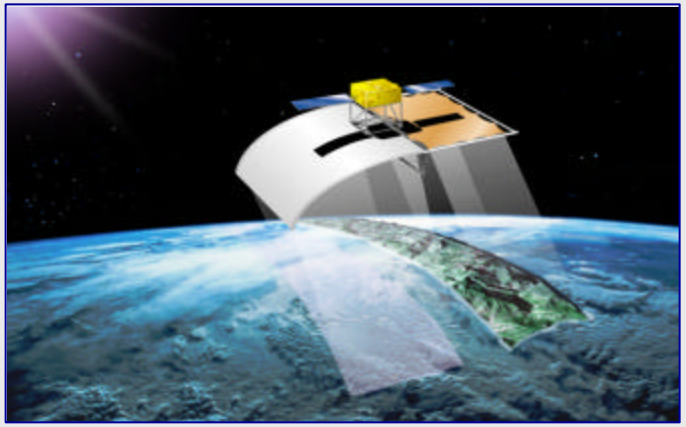
- 5-20m class antenna for 2km horizontal resolution with wide-swath scan
- Potential extension to geostationary orbits

Natural Hazard



- 3x10m antennas for wide-swath/high SNR LEO, 30m class for GEO

Strawman Technology Validation Experiment: Inflatable Antennas for Earth Science Applications



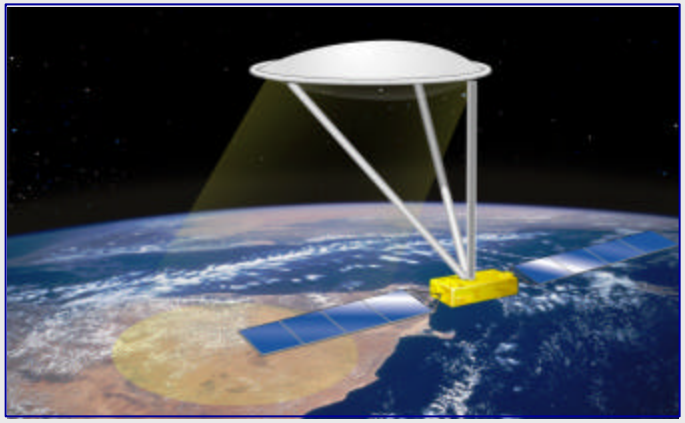
Antenna Type: Half Planar (5x3m)
Half Cylindrical Parabola (5x7m-curved)

Heritage: ESP IIP; inflatable planar array ground demonstration

Frequency: 1-35 GHz

Tech. Validation Objectives:
- packaging/deployment
- surface shape control/roughness
- material rigidization/survivability
- ~1 yr. duration

Applications:
- Cylindrical parabola for precipitation radar measurements with high resolution/wide swath
- Natural hazard studies with SAR



Antenna Type: Lenticular Off-Set Parabola (16m-diameter)

Heritage: Inflatable Antenna Experiment (Shuttle experiment '96)

Frequency: 1-35 GHz

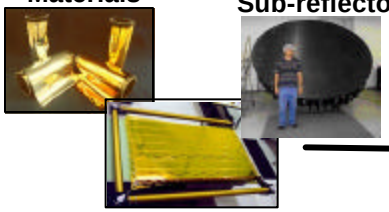
Tech. Validation Objectives:
- packaging/deployment
- surface shape control/roughness
- material rigidization/survivability
- pointing control
- ~1 yr. duration

Applications:
- Soil moisture measurements at ~10km resolution
- Meteorological radar measurements at GEO

Integrated Technology Plan for Large Deployable Reflector Antennas

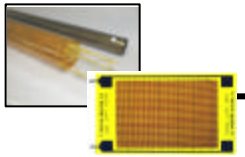
Rigidizable Materials

Adaptive RF Sub-reflectors



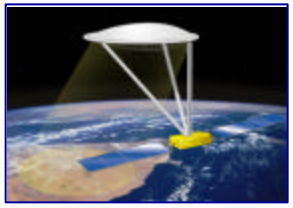
Membranes for Waveguides

Inflatable Trusses



Actuators & Sensors for Control

NMP Validation Flight



Strawman

Soil Moisture Science Mission

Launch

Launch

Formulation | **Implementation**

Demonstrate deployment, rigidization, control and survivability of large inflatable antenna

- 16m diameter class antenna, 150 kg
- Shape control of antenna surface
  - Surface smoothness vs. frequency
- Control of flexible structure dynamics
- Pointing accuracy/control
- Effects of out-gasing/thermal loads

Enhanced Soil Moisture Measurement

- 10km spatial resolution enabled by 25m class antenna
- Passive/active remote sensing

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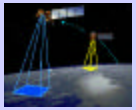
Intelligent Distributed Spacecraft Infrastructure for Constellation Observatory

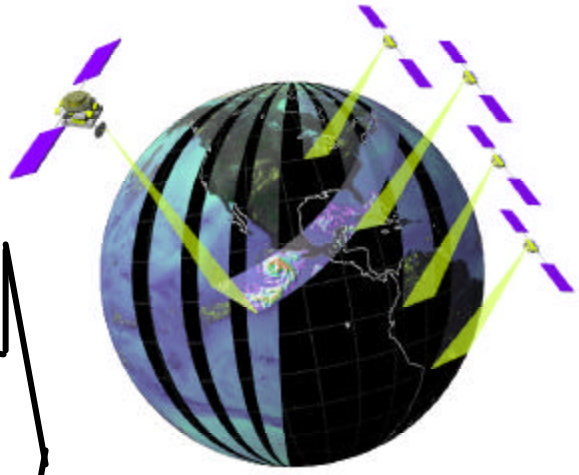
Formation Flying

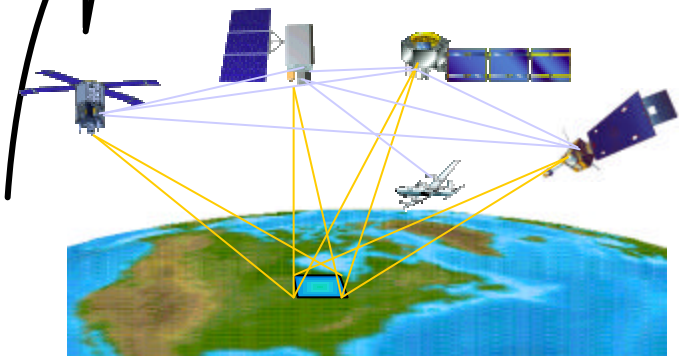



- Autonomous reconfiguration
- Closed-loop platform control
- Coordinated observations
- Orbit maintenance
- Interspacecraft communications

Sensor/Satellite Networks

- Continuous communication coverage via asymmetric, hybrid links
- Management of complex, multi-node heterogeneous networks
- Scalable design for incremental network growth
- Graceful degradation to network performance during stress
- Robust routing, adaptive bandwith allocation, and intelligent power control of nodes





Global Precipitation Measurements

- Integrated observatory with autonomous constellation control/operation
- Inter-satellite communications
  - Optimize science return with data link capacity
  - Space/Ground Protocol
  - Data downlink via commercial network

Future Observation Systems

- Provide intelligent infrastructure to support sensor web

Integrated Technology Plan To Enable Global Precipitation Measurements

Objective:

- Provide systematic estimation of global precipitation with three hours or less sampling interval
  - Improved weather forecasting
  - Global water cycle understanding

Strawman

Global Precipitation Observation Strategy


Imager


Dual-Freq. Radar Elec.

Drone Radiometers

Baseline LEO Science

Enhanced LEO Science/GEO Science

Launch

- **Formation Flying**
- **Inter-satellite communications**
- **Robust routing, adaptive bandwidth**

NMP Validation Flight

Launch

Inflatable Antenna

FY 00 01 02 03 04 05 06 07 08 09 10

Breakout Session Objectives

- Clarify the relevance of each class of technologies for future ESE science mission objectives
  - new science investigations enabled by technologies
    - new measurement type, new vantage points (MEO, GEO, L1, L2)
    - requirements for spatial, temporal, or spectral resolution or sampling
    - needed by multiple measurement approaches?
  - anticipated time scale for science mission
- Define technology development/flight validation needs
  - capabilities that require new technology development
- Identify requirements for flight validation
  - justification
  - objectives, scope, and milestones
  - top-level validation flight development scenario

Breakout Session Chairs and Facilitators

TOPIC	Co-chair	Co-chair	Facilitator
Lightweight Deployable Antennas	R. Kakar, NASA HQ	D. Schaubert, U Mass	M. Lou JPL
High Rate Comms	G. Prescott, NASA HQ	K.Bhasin, GRC	F. Lansing, JPL
Deployable Telescopes	E. Browell, LaRC	F. Peri, GSFC	R. Connerton, GSFC
Distributed S/C Infrastructure	M. Schoeberl, GSFC	J. Bristow, GSFC	C. Raymond, JPL
Precision Navigation	J. LaBrecque, NASA HQ	P. Axelrad, U Colo.	J. Hartley, GSFC
Onboard Data Processing	E. Paylor, NASA HQ	G. Bothwell, JPL	A. Walton, JPL
Integrated Optics and Spectral Dispersion Technologies	D. Wickland, NASA HQ	J. Gleason, GSFC	D. Crisp, JPL
Laser Technology	U. Singh, LaRC	J. Spinhirne, GSFC	R. Menzies, JPL
Innovative technologies	L. Schuster, NASA HQ	B. Wilson, JPL	M. Buehler, JPL

Breakout Session Approach

Presentations (10 to 15 minutes each)

- Invited Talks/Contributed Talks
  - Science needs and measurement requirements
  - Technology capability needs

Discussion

- Identify matches between science needs and technology capabilities
- Identify technology/capability trades, etc.

Preparation of Products

Breakout Session Products

Science Capability Need

- Relevance to Future ESE Science Missions
- Science / Measurement Requirements
  - Application to Multiple Missions

Candidate Technology

- Description/Illustration of Technology
- Technology Development Roadmap

Implementation

- Ground development / Validation
- Flight Validation
  - Description/Justification/Benefits
  - Accommodation Requirements / Schedule